national accelerator laboratory

EXP-54
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EXPERIMENTALISTS: R. Cassel, S. Mori, R. Stiening, E. J. N. Wilson
OBJECT: Study of Resonance Crossing in the Parabola
DATE PERFORMED: October 5th, 1973

1. Motivation

Recently, considerable attention has been devoted to correcting stopbands at injection and tuning the Main Ring quadrupoles to a working point which avoids those stopbands which remain.

During the parabola (8 to 20 GeV) these are indications that stopbands which are compensated during injection reappear, driven perhaps by multipole fields generated by eddy currents which are excited in the vacuum chamber by the rising field. Differences in the dynamic characteristics of the quadrupole and dipole magnet system, their power supplies and reference fields, need not be large to cause the working point to wander in the parabola and cross these stopbands. That such effects occur is clear from the fact that sudden beam losses are commonly seen in the parabola and may be minimized by applying crude step functions in the quadrupole power supply programme.

This experiment was performed to investigate the locus of the working point in the parabola with a view to programming the quadrupole current waveform to hold the tune steady. In the absence of a programmed tune split control one can only hope to affect the average tune value. Individual control of ν_x and ν_y must await implementation.

2. Measurement of Currents in the Parabola

We traced the currents in both dipoles and quadrupoles during the parabola from its onset at 0.9 seconds to the point where the steady 100 GeV/sec rise is entered at 1.10 seconds. The difference, $I_B - I_Q$, was measured directly by triggering a DVM monitoring a tranductor surrounding the dipole and quadrupole bus bars. The currents in the two bus bars flow in opposite directions through the transductor. We calculated the average tune, $(\nu_x + \nu_y)/2$, from the measurements (Fig. 1).

3. Measurement of Tune in the Parabola

As a cross check we measured the tune in each plane at each point in the parabola. The measurement was made by triggering a pinger and counting the frequency of the coherent oscillations from photographs of a position-sensor output. The mean tune obtained in this way agrees very well with that predicted from current measurements (see Figure 1). Clearly the tranductor is a good measure of the guide field.

4. Correlation of Tune Measurements with Beam Loss

Fig. 2 shows the variation of ν_x and ν_y measured in the parabola. Also plotted is the intensity profile measured at the same tune. (All these measurements were made after emptying out the empirical "bumps" from the quadrupole power supply.)

Both ν_x and ν_y cross or approach the third order resonance near the beginning of the parabola ($t = 0.97$ sec). At this point $\dot{B}$ is still weak and the compensation of this resonance made at injection is still partially effective. Nevertheless the intensity declines steeply while the tune remains close to 20.33.

At 1.10 seconds the horizontal tune recrosses 20.33. This is near the top of the parabola where $\dot{B}/B$ is maximum and eddy current effects are strongest. One would expect the 20.33 stopband to be uncompensated and quite deep under these conditions and this is confirmed by the abrupt beam loss coincident with the crossing.

An earlier and smaller step in intensity ($t = 0.92$ sec) would seem to be correlated with the point where $\nu_x = \nu_y$ and where one might expect large horizontal betatron amplitudes to couple into the vertical plane and be lost to the narrow vertical operture of the machine.

5. Conclusions

The features of loss in the parabola seem well correlated with changes in the ratio I_Q/I_B and the reemergence of third order stop bands excited by eddy current fields.

Clearly the present power supply regulation system does not hold I_Q/I_B constant and should be modified to do so. Once this is done there is every hope that the tune will remain constant and losses due to resonance crossing can be avoided without recourse to empirical "bumps" in the quadrupole current program.

The problem of coupling when $\nu_x = \nu_y$ will be avoided when it becomes possible to control F and D quadrupole currents independently. Depressing the injection value of ν_x below ν_y will avoid this coupling resonance at low energy where betatron amplitudes are large.

E. J. N. Wilson

EJNW:mc

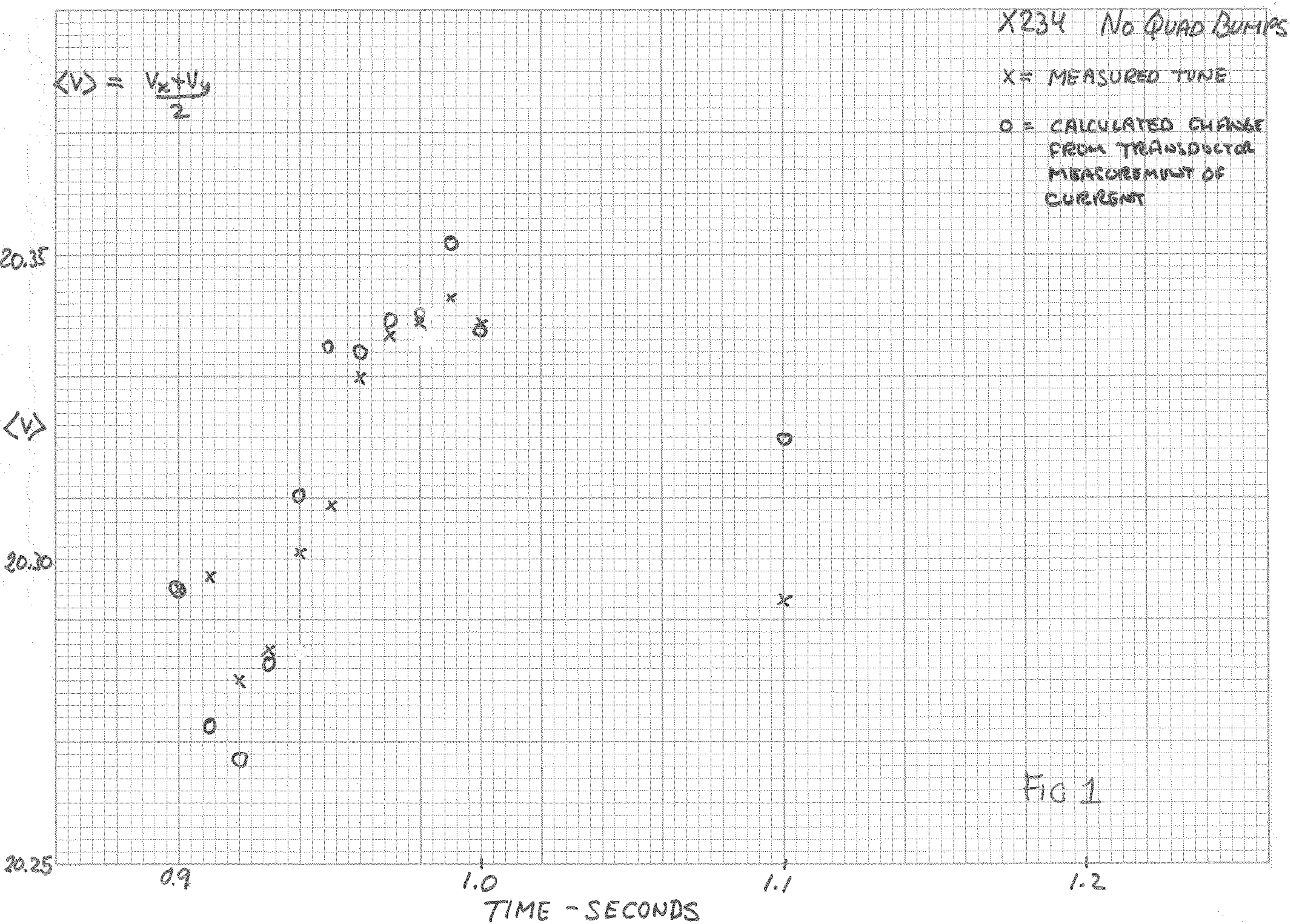
X234 No Quad Bumps
$\langle \nu \rangle = \frac{\nu_x + \nu_y}{2}$
X = MEASURED TUNE
O = CALCULATED CHANGE FROM TRANSDUCTOR MEASUREMENT OF CURRENT
20.35
$\langle \nu \rangle$
20.30
20.25
0.9
1.0
1.1
1.2
TIME - SECONDS

Fig 1

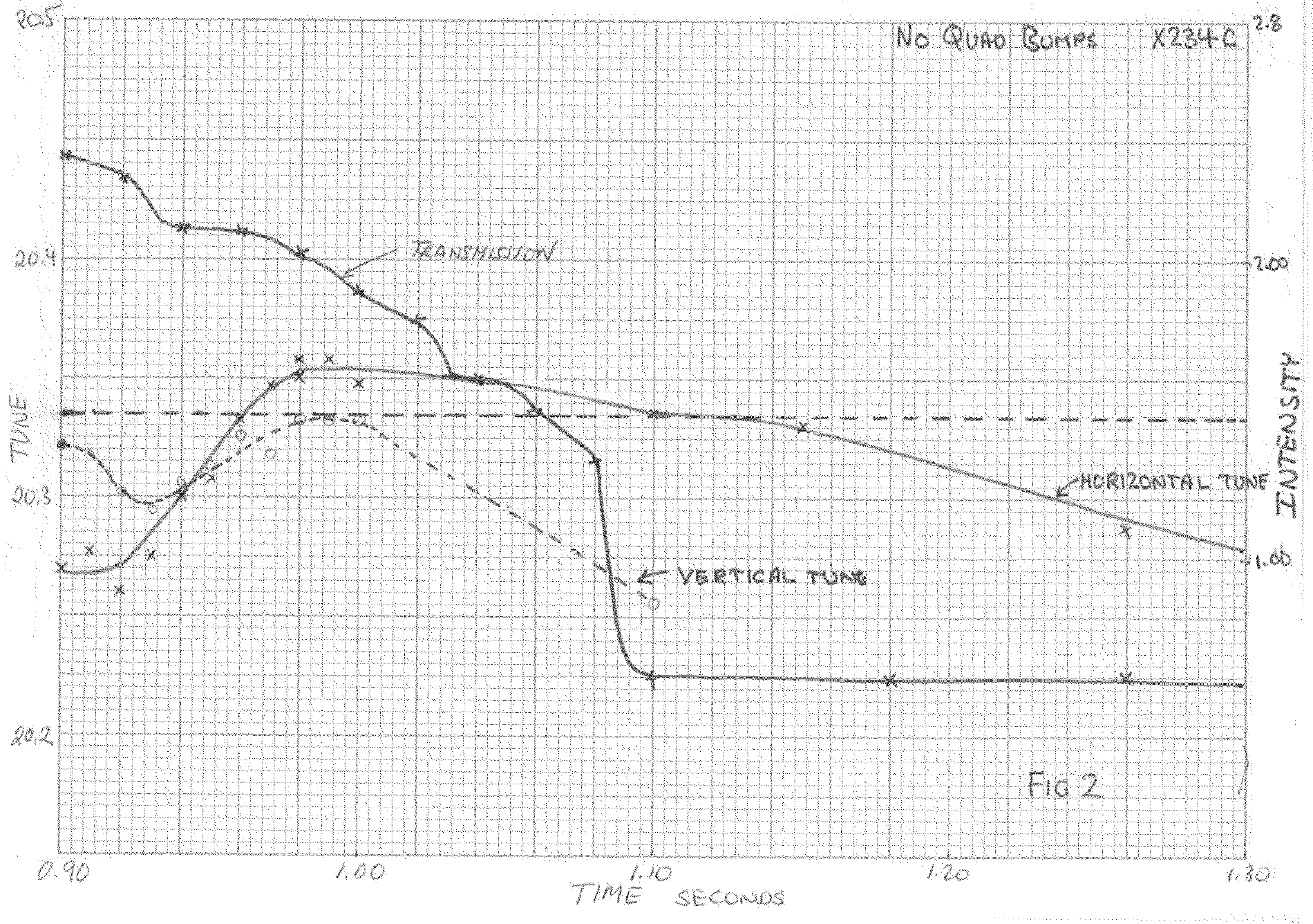
No Quad Bumps X234C
20.5
20.4
20.3
20.2
TUNE
2.8
2.00
1.00
INTENSITY
TRANSMISSION
HORIZONTAL TUNE
VERTICAL TUNE
0.90
1.00
1.10
1.20
1.30
TIME SECONDS

Fig 2